A-6031
[1-8]

RESEARCH ARTICLE Indian Journal of Agricultural Research

Influence of Maturity Duration on Grain Yield of Rice under Direct-seeded Condition in the Tropics

D. Sumith de Z. Abeysiriwardena[1], A.A. Prasadika M. Athauda[1], W.S. Priyantha[2], V. Samiduni Jayasinghe[3]

10.18805/IJARe.A-6031

ABSTRACT

Background: The optimum maturity duration for maximum grain yield of non-photosensitive rice (*Oryza sativa*) under direct-seeded condition in the tropics was studied. Information on such studies conducted using near-isogenic rice lines are lacking. Change in yield with maturity duration was explained using yield components.

Methods: The experiment was conducted in the dry zone of Sri Lanka over two seasons namely dry and wet during 2021 and 2022. Non-photosensitive near-isogenic rice lines that are varying in maturity duration from 80 to 120 days but with 94.0% genetic uniformity were used as simple treatments in the study. Pre-germinated seeds of isogenic lines were direct-seeded in the experimental plots.

Result: The most appropriate relationship between maturity duration and grain yield was cubic and the optimum maturity duration for the maximum grain yield was falling within 105 to 111 days in both dry and wet seasons under direct-seeded condition in non-photosensitive rice in the tropical climate. Number of panicles/m^2 and number of spikelets/panicle influenced to change the grain yield of rice with the change in maturity duration.

Key words: Direct-seeded condition, Grain yield, Maturity duration, Near-isogenic lines, Rice.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population (FAO, 2019). Demand for rice is estimated to be 852 million tons by 2035 (Khush, 2013). Thus increasing rice productivity and production are important. Maturity duration of rice contributes to the final grain yield (Singh *et al*., 2017) and it is under genetic control (Zeng *et al*., 2017). Rice varieties differ greatly in maturity duration (Babu *et al*., 2014). Commonly grown rice varieties in the tropics are non- photosensitive and their maturity duration ranges from about 80 to 125 days. About 120 day maturity duration appeared to be the optimum for maximum yield under well fertilized conditions in the tropics (Yoshida, 1981; Tanaka and Vergara, 1967).

All the studies related to optimum maturity duration for maximum grain yield of non-photosensitive rice in the tropics have been conducted using different varieties with different genetic constitutions to represent different maturity durations under transplanted condition. Results of the studies conducted under transplanted condition are not applicable to direct-seeded condition. Recently direct-seeded rice area in Asia is estimated to be about 29 million ha covering approximately about 21% of the total rice area (Alam *et al*., 2020). In addition, accuracy of relating differences in grain yield of varieties to different maturity durations was questionable as long as the genetic background of those varieties were not uniform.

So far, no study on the relationship between maturity duration and grain yield of rice under direct-seeded condition using genetically uniform near-isogenic lines has been conducted in rice. Grain yield of rice is a function of the four yield components *viz*. number of panicles/unit area, the number of spikelets/panicle, filled grain% and the 1000 grain weight. In order to explain any observed differences in grain yield due to differences in maturity duration, yield components should also be studied. Thus, the objectives of the present study were to ascertain the optimum maturity duration that can produce the maximum grain yield and to study the yield components that are contributing to increase in grain yield at optimum maturity duration of rice under direct-seeded condition in the tropics using near-isogenic lines.

[1]Rice Breeding Unit, CIC Agribusinesses, Pelwehera, Dambulla, Sri Lanka.
[2]Rice Research and Development Institute, Batalagoda, Ibbagamuwa, Sri Lanka.
[3]Department of Environmental Management, Faculty of Science, University of Kelaniya, Dalima, Sri Lanka.

Corresponding Author: D. Sumith de Z. Abeysiriwardena, Rice Breeding Unit, CIC Agribusinesses, Pelwehera, Dambulla, Sri Lanka. Email: sumithab@sltnet.lk

How to cite this article: Abeysiriwardena, D.S.d.Z., Athauda, A.A.P.M., Priyantha, W.S., Jayasinghe, V.S. (2023). Influence of Maturity Duration on Grain Yield of Rice Under Direct-seeded Condition in the Tropics. Indian Journal of Agricultural Research. doi: 10.18805/IJARe.A-6031.

Submitted: 14-07-2022 **Accepted:** 18-01-2023 **Online:** 09-02-2023

MATERIALS AND METHODS

The study was carried out at the rice research field of CIC Agribusinesses in the dry zone of Sri Lanka under the tropical climate over two seasons namely dry and wet in 2021 and 2022. On the average, day length is about half an hour longer during the dry season than that of during the wet season. Daily mean temperature during the dry and wet seasons were 27.87°C and 26.55°C, respectively. The experiments in both seasons were conducted under irrigated condition.

Eighteen and twenty-two (same eighteen and four additional) near-isogenic rice lines that are varying in maturity duration from 85 to 120 days with 94.0% genetic uniformity were used in the dry and wet seasons, respectively. Both the experiments in the dry and wet seasons were laid out in the randomized complete block design (RCBD) with two replications. Plot size was 3 m × 3 m. Pre germinated seeds of each isogenic-line were direct-seeded in the relevant plot in each block. The isogenic-lines with different maturity durations were established in the field in such a way that all the lines would mature within about 10 day period.

Number of days from date of sowing to date of physiological maturity was counted for each isogenic line and recorded as the growth duration in number of days. Plots were harvested at physiological maturity. Weight of cleaned rough rice grains of each plot was recorded at 14% seed moisture level. Number of panicles/m^2, number of spikelets/panicle, filled-grain % and 1000 grain weight were recorded at maturity as four yield components. Grain yields of isogenic lines were also estimated using yield components.

Data in dry and wet seasons were analyzed separately using ANOVA. Relationships of maturity duration with grain yield and yield components were estimated using linear, quadratic and cubic regressions as needed. Relationship between actual and estimated grain yield was estimated using linear regression and relationships between actual grain yield and no. of panicles/m^2, no. of spikelets/panicle, filled grain% and 1000 grain weight were estimated using linear, quadratic and cubic regressions.

RESULTS AND DISCUSSION

Maturity duration and grain yield

All the rice isogenic lines matured as expected within a period of about 10 days so that all the lines were exposed to almost the same weather condition during maturity in both seasons. Thus, any yield difference among lines due to difference in weather cannot be expected. No serious yield damage was observed in any of the plots due to pests and diseases.

Maturity duration and grain yield of near isogenic lines of rice cultivated under direct-seeded condition in the dry

Table 1: Maturity duration and grain yield of near isogenic lines of rice under direct-seeded condition in the dry and wet seasons in tropical climate of Sri Lanka.

Isogenic line	Maturity duration (days)		Grain yield (t/ha)	
	Dry season	Wet season	Dry season	Wet season
10-1-1	-	117	-	5.72
17-3-1	-	117	-	5.55
24-3-2	-	115	-	6.54
17-2-1	124	116	3.87	5.08
10-2-1	120	115	3.61	5.31
3-2-2	112	105	5.75	7.45
8-1-8	110	106	5.20	7.43
3-3-2	109	105	4.66	7.35
3-3-3	108	110	4.99	6.57
4-2-2	107	107	4.99	7.50
8-8-2	107	104	5.85	6.60
8-2-1	101	102	4.50	5.97
3-3-1	100	104	3.92	6.49
1-1-1	99	99	3.84	5.09
11-4-2	97	96	3.79	4.88
13-1-2	95	100	4.33	5.91
12-1-2	93	98	3.71	4.93
5-5-1	92	99	4.28	5.76
13-9-2	90	91	3.74	4.52
1-4-1	89	91	3.91	5.00
11-2-1	85	89	4.26	5.06
17-1-4	-	87	-	5.08
LSD at p= 0.05	1.95	1.73	0.62	1.02

-Indicates data not available in the dry season.

and wet seasons in the tropical climate of Sri Lanka are presented in Table 1. The maturity duration varied significantly ($P<0.0001$) among rice isogenic lines in the dry as well as in the wet season. Some lines recorded comparatively longer maturity duration in the dry season with longer days probably due to slight photosensitivity. Dat and Peterson (1983) reported that some rice varieties are sensitive to photoperiod differences of only a few minutes. Some lines recorded comparatively longer maturity duration in the wet season with comparatively lower temperature probably due to temperature sensitivity while others recorded almost the same maturity duration in both seasons. However, the variation in maturity duration among lines within a season may be attributed to genetic variability.

The grain yields among rice isogenic lines were also found to be significant ($p<0.0001$) in both seasons. All the isogenic lines recorded higher grain yields in the wet season than that of in the dry season and this may be due to low temperature effect during the wet season (26.55°C) than in the dry season (27.87°C). Within a moderate range, low temperature favors increase in grain yield in rice (Wang *et al*., 2016).

The linear, quadratic and cubic relationships between maturity duration and grain yield of isogenic lines were estimated in two seasons separately. In both seasons, the linear relationships between maturity duration and grain yield were found to be not significant while the quadratic relationships were found to be significant at $p=0.01$ with correlation coefficients (r) less than 0.68. However, the most appropriate significant ($p<0.001$) relationship between grain yield and maturity duration of rice was found to be cubic in both seasons where the 'r' values were 0.795 and 0.890 in the dry and wet seasons, respectively (Fig 1).

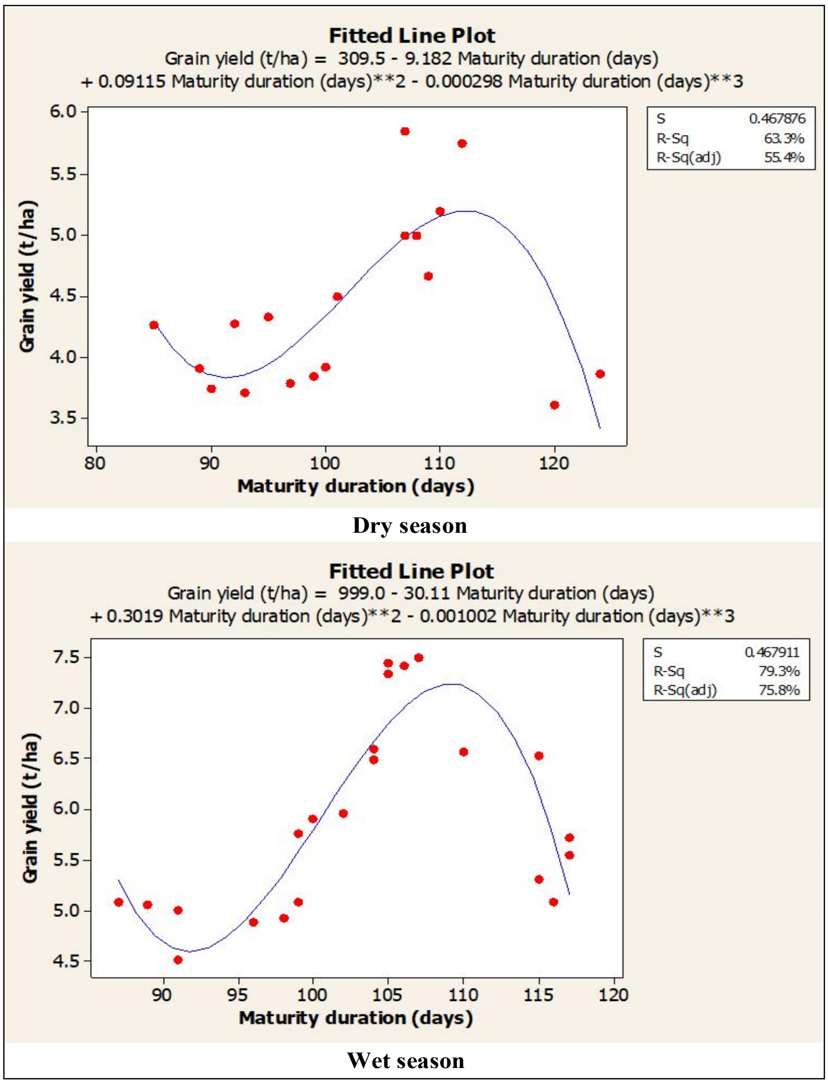

Fig 1: Cubic relationships between grain yield and maturity duration of rice isogenic lines under direct-seeded condition in the dry and wet seasons in the tropical climate of Sri Lanka.

In the dry as well as in the wet season, the grain yield of rice increased when the maturity duration increased from about 90 to 105-111 days and then started to decrease with the increase in maturity duration indicating that the highest yielding maturity duration of rice is within the range of 105 to 111 days (closer to 105 days in the wet season and closer to 111 days in the dry season) under direct-seeded condition in the tropical climate in Sri Lanka irrespective of the season. Interestingly, same isogenic lines of 3-2-2, 8-1-8, 3-3-2, 3-3-3, 4-2-2 and 8-8-2 recorded the highest grain yield in both seasons.

Findings in the present study are not in agreement with Yoshida (1981), Tanaka and Vergara (1967) and Vergara *et al*. (1966) who reported that about 120 day maturity duration appeared to be optimum for maximum grain yield in rice under transplanted conditions in the tropics. Vergara *et al*. (1964) also reported that the optimum growth duration for the maximum grain yield was about 111 days under transplanted condition by manipulating the maturity duration using a photoperiod sensitive rice variety. However, the present study differed from above studies as it used genetically uniform near isogenic lines of rice with varying maturity durations under direct-seeded condition.

Another observation in the present study was that the grain yield did not decrease as expected though the maturity duration decreased from about 90 to 85 days indicating that varieties with maturity duration shorter than even 90 days may be developed without sacrificing yield. Such varieties with ultra-short maturity duration can be cultivated in drought prone areas to escape from drought (Abeysiriwardena *et al*., 2011).

Maturity duration and yield components

Maturity duration may influence grain yield indirectly through the yield component traits (Li *et al*., 2019). Thus, The relationship of maturity duration with four yield components namely number of panicles/m^2, number of spikelets/panicle, filled grain% and 1000 grain weight were studied in two seasons separately.

The number of panicles/m^2, number of spikelets/ panicle, filled grain%, 1000 grain weight and the estimated grain yield using yield components of rice isogenic lines under direct-seeded condition in dry and wet seasons in the tropical climate are presented in Table 2. To judge the accuracy of the yield components measured, the relationship between actual grain yield and the estimated

Table 2: The number of panicles/m^2, number of spikelets/panicle, filled grain%, 1000 grain weight and the estimated grain yield using yield components of rice isogenic lines under direct-seeded condition in dry and wet seasons in tropical climate of Sri Lanka.

Isogenic line	No. of panicles/m^2		No. of spikelets/panicle		Filled-grain (%)		1000 grain weight (g)		Estimated grain yield (t/ha)	
	D*	W	D	W	D	W	D	W	D	W
10-1-1	-	372	-	88	-	82	-	23.0	-	6.1
17-3-1	-	350	-	93	-	78	-	21.3	-	5.51
24-3-2	-	337	-	103	-	76	-	21.9	-	5.78
17-2-1	383	294	95	91	64	67	18.5	22.4	4.33	4.01
10-2-1	315	322	84	94	67	74	20.6	21.7	3.66	4.86
3-2-2	257	375	129	112	86	74	21.4	22.1	6.08	6.87
8-1-8	274	345	123	103	76	76	25.5	26.2	6.46	7.01
3-3-2	315	380	109	114	86	77	19.8	21.0	5.87	7.00
3-3-3	344	355	110	106	74	76	18.9	21.6	5.25	6.18
4-2-2	250	311	109	110	88	84	23.6	23.5	5.60	6.75
8-8-2	360	320	114	104	75	77	21.3	23.2	6.53	5.48
8-2-1	325	349	91	84	73	79	20.2	23.4	4.78	5.28
3-3-1	388	326	71	93	69	76	20.0	22.5	3.81	5.39
1-1-1	316	271	90	83	74	77	20.3	21.4	4.26	3.65
11-4-2	334	210	78	85	73	87	21.2	23.0	4.00	3.16
13-1-2	376	316	93	94	67	76	21.5	22.0	5.05	5.68
12-1-2	296	238	87	89	79	75	22.6	23.9	4.53	3.85
5-5-1	309	283	92	89	78	82	22.9	23.1	5.11	4.36
13-9-2	342	238	89	82	72	79	21.4	19.9	4.71	2.99
1-4-1	363	222	92	79	63	81	21.9	22.2	4.60	3.02
11-2-1	352	244	81	77	83	81	20.1	22.4	4.78	3.41
17-1-4	-	316	-	75	-	81	-	22.9	-	4.39
LSD at p= 0.05	97.2	57.6	30.9	13.3	NS	NS	1.09	0.70	-	-

-Indicates data not available, NS- Not significant.

grain yield using yield components was established for both seasons separately. This relationship was found to be positive linear with highly significant ($p = <0.001$) correlation coefficients of $r = 0.91$ and $r = 0.93$, in the dry and wet seasons, respectively so that yield components have been accurately measured and this allowed to study the relationship of maturity duration with four yield components.

In the dry season, out of the four yield components two yield components namely number of panicles/m^2 and the filled grain% were found to be not significant and the other two yield components namely number of spikelets/panicle and 1000 grain weight were found to be significant at $p = 0.05$ and $p = 0.0001$, respectively. All the relationships of linear, quadratic and cubic between maturity duration and 1000 grain weight were found to be not significant indicating that maturity duration has not influenced the 1000 grain weight. However, out of quadratic and cubic relationships between maturity duration and number of spikelets/panicle, the most significant and appropriate relationship was found to be cubic ($p = 0.002$) with $r = 0.78$.

In the wet season, only the filled grain% was found to be not significant and number of panicles/m^2, number of spikelets/panicle and 1000 grain weight were found to be significant at $p<0.0001$. All the relationships of linear, quadratic and cubic between maturity duration and 1000 grain weight were found to be not significant indicating that maturity duration has not influenced 1000 grain weight. The most significant and appropriate relationships of maturity duration with number of spikelets/panicle and number of panicles/m^2 in the wet season were cubic at $p<0.001$ and $p = 0.002$, respectively with both having $r = 0.81$.

Cubic relationships between maturity duration and number of spikelets/panicle in the dry and wet seasons are presented in Fig 2. This cubic relationship is as same as that of between maturity duration and grain yield so that

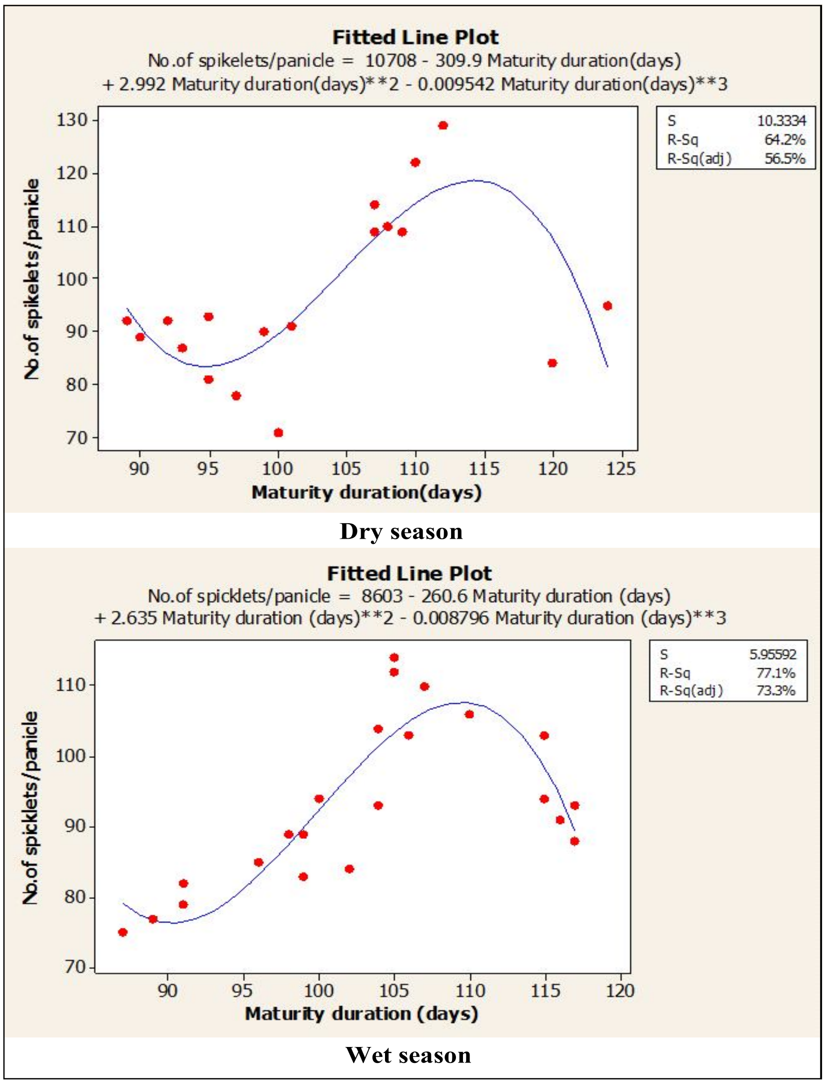

Fig 2: Cubic relationships between no. of spikelets/panicle and maturity duration of rice isogenic lines under direct-seeded condition in the dry and wet seasons in the tropical climate of Sri Lanka.

number of spikelets/panicle influenced the grain yield variability due to change in maturity duration in both the dry and wet seasons in rice under direct-seeded condition in the tropical climate. This is further confirmed by the significant positive linear relationships (p= 0.0001) between grain yield and number of spikelets/panicle with r= 0.87 where grain yield increased with the increase in number of spikelets/panicle in both the dry and wet seasons (Fig 3). This is in agreement with Vergara *et al*. (1964) who reported that the highest yielding maturity duration produced the highest number of spikelets and grains/panicle.

The most appropriate significant relationship between maturity duration and number of panicles/m^2 was found to be cubic at p=0.002 with r=0.81 (Fig 4). The number of panicles/m^2 of rice increased with the increase in maturity duration from about 93 to 110 days and then started to decrease with further increase in maturity duration indicating that the highest number of panicles/m^2 was associated with the maturity duration of about 110 days. Thus, the change in maturity duration also influenced the grain yield variability through the number of panicles/m^2 in the wet seasons in rice. This was further confirmed by the significant positive linear relationship between grain yield and the number of panicles/m^2 at p= 0.0001 with r= 0.72 where grain yield increased with the increase in number of panicles/m^2. in the wet season (Fig 5). Influence of the number of panicles/m^2 in addition to the number of spikelets/panicle on grain yield may be the reason for the comparatively higher grain yield in the wet season. Li *et al*. (2019) also reported that grain yield is indirectly influenced by maturity duration through yield components.

Maturity duration in variety yield improvement

In rice variety improvement programs, the target maturity duration should be within the range of 105 to 111 days under

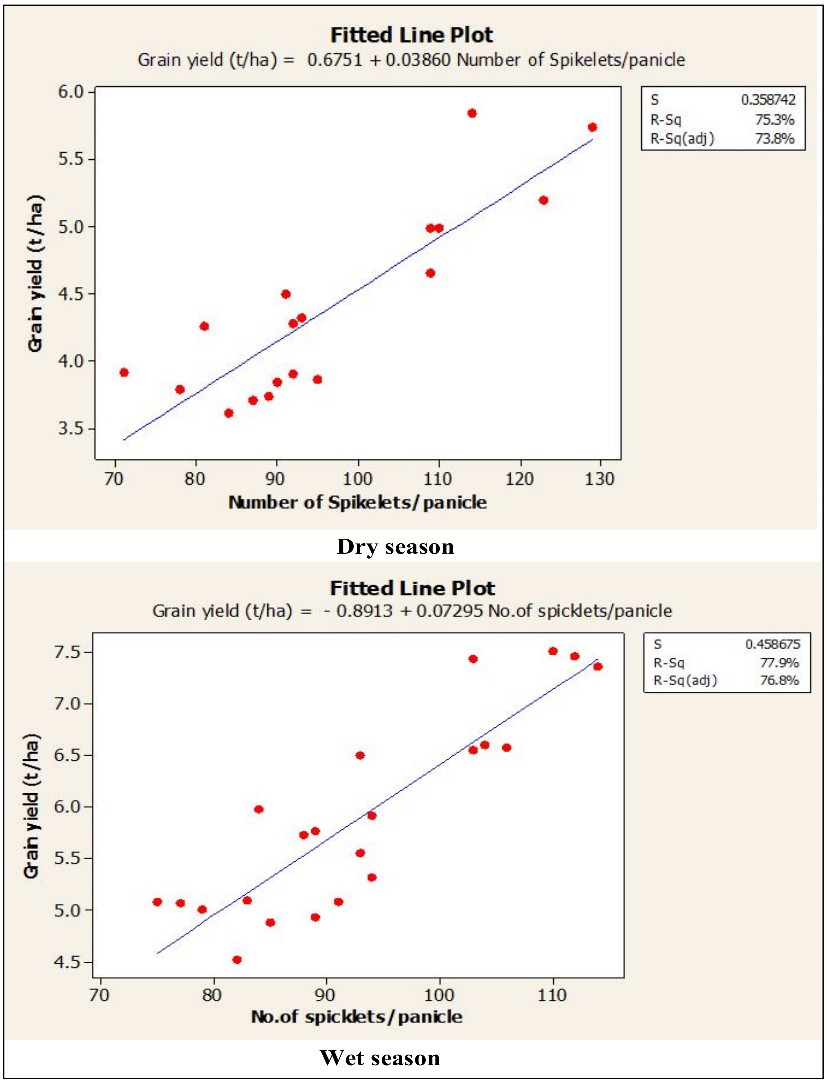

Fig 3: Linear relationships between grain yield and the number of spikelets/panicle of rice isogenic lines under direct-seeded condition in the dry and wet seasons in the tropical climate of Sri Lanka.

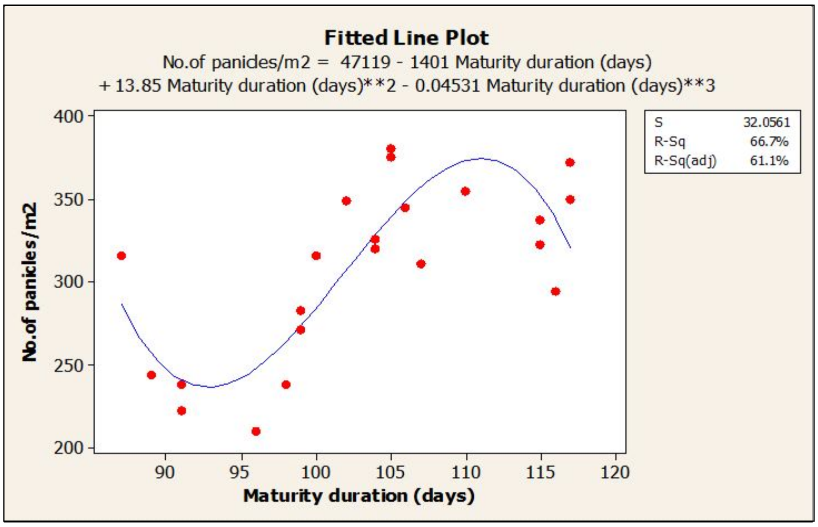

Fig 4: Cubic relationship between maturity duration and number of panicles/m^2 of rice isogenic lines under direct-seeded condition in the wet season in the tropical climate of Sri Lanka.

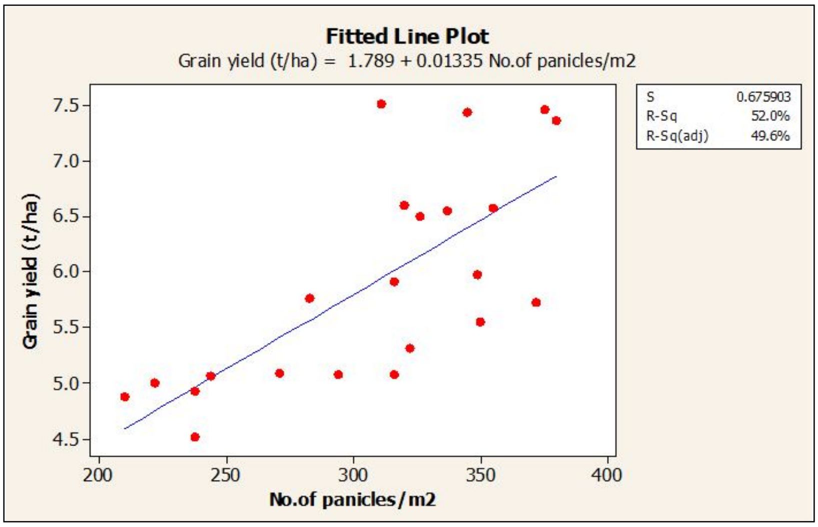

Fig 5: Linear relationship between grain yield and the number of panicles/m^2 of rice isogenic lines under direct-seeded condition in the wet season in the tropical climate of Sri Lanka.

direct-seeded condition in the tropics. Thus, developing rice varieties that mature within 105 to 111 days with the highest number of spikelets/panicle if combined with thousand grain weight which is independent of level of grain yield and number of spikelets/panicle within the observed limits may make a jump in variety improvement for high grain yield under direct-seeded condition in the tropics. However, this has to be confirmed by further studies.

CONCLUSION

The most appropriate relationship between maturity duration and grain yield was found to be cubic and the optimum maturity duration for the maximum grain yield is within 105 to 111 days under direct-seeded condition in non-photosensitive rice in both dry and wet seasons in the tropical climate. The number of spikelets/panicle was the main yield component that influenced to change the grain yield with the change in maturity duration.

Conflict of interest: None.

REFERENCES

Abeysiriwardena, D.S. de Z., Balasooriya, B.A.N.K., Somaratne, N.S., Dissanayake, D.M.N. (2011). Minimizing the water supply duration in the field with no reduction of grain yield in the variety Bg 250 of the ultra-short maturity class. J. Natn. Sci. Foundation Sri Lanka. 39(1): 43-52.

Alam, K., Bell, R.W., Hasanuzzamars, M., Salahim, N., Rashid, M.H., Akter, N., Isalm, M.S., Islam, S., Naznin, S., Arik, M.F.A., Apu, M.R.B., Saif, H.B., Alam, M.J., Khatun, F. (2020). Rice (*Oryza sativa* L.) establishment techniques and their implications for soil properties, global warming potential mitigation and crop yields. Agronomy. 10: 888; doi:10.3390/agronomy 10060888.

Babu, S., Singh, R., Avasthe, R.K, Yadav, G.S., Chettri, T.K. (2014). Production potential, economics and energetic of rice varieties under different methods of production in organic management conditions of Sikkim Himalayas. Indian Journal of Agronomy 59(4): 602-606.

Dat, T.V. and Peterson, M.L. (1983). Performance of near-isogenic genotypes of rice differing in growth duration. 1. Yield and yield components. Crop Science. 23: 239-242.

FAO. (2019). FAOSTAT Production Data www.fao.org/faostat/en/#data.

Khush, G.S. (2013). Strategies to increase yield potential of cereals: Case of rice as an example. Plant Breeding. 132: 433-436.

Li, R., Li, M., Ashraf, U., Liu, S., Zhang, J. (2019). Exploring the relationship between yield and yield related traits for rice varieties released in China from 1978 to 2017. Front. Plant Sci. 10:543. doi:10.3389/fpls.2019.00543.

Singh, A., Singh, Y., Singh, R., Jat, A.L. (2017). Weed dynamics and production potential of direct-seeded rice cultivars as influenced by weed management. Indian Journal of Weed Science. 49(2): 108-112.

Tanaka, A. and Vergara, B.S. (1967). Growth habit and ripening of the rice plants in relation to the environmental conditions in the Far East. I.R.C. Newsl. (Special issue): 26-42.

Vergara, B.S., Thanaka, A., Lilis, R., Puranabhavung, S. (1966). Relationship between growth duration and grain yield of rice plant. Soil Science and Plant Nutrition. 12(1): 31-39.

Vergara, B.S., Lilis, R., Tanaka, A. (1964). Relationship between length of growing period and yield of rice plants under a limited nitrogen supply. Soil Science and Plant Nutrition. 10(2): 15-21.

Wang, D., Laza, M.R., Cassman, K.G., Huang, J., Nie, L., Ling, X., Centeno, G.S., Cui, K., Wang, F., Li, Y. (2016). Temperature explains the yield difference of double season rice between tropical and subtropical environments. Field Crops Res. 198: 303-311.

Yoshida, S. (1981). Rice plant characters in relation to yielding ability. In Fundamentals of Rice Crop Science. International Rice Research Institute, P.O. Box 933, Manila, Philippines. pp. 213-230.

Zeng, D., Tian, Z., Rao, Y., Dong, G., Yang, Y., Huang, L. (2017). Rational design of high-yield and superior-quality rice. Nat. plants 3:17031.10.1038/nplants.2017.31.